ON THE

BRAIN OF CHIMÆRA MONSTROSA.

BY

BURT G. WILDER, M.D.,

PROFESSOR OF COMPARATIVE ANATOMY AND ZOOLOGY, CORNELL UNIVERSITY.

WITH ONE PLATE.

Published July 24, 1877.

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Introduction.—At the close of a paper upon the brains of the fish-like vertebrates presented before this Academy on the 4th of April, 1876, I exhibited a fairly preserved adult male example of *Chimæra monstrosa*,[1] together with a drawing of the brain as then partly exposed. After calling attention to certain peculiarities which apparently had not before been observed, I expressed the intention of preparing a full description of it with figures for presentation to the Academy at a future meeting.

In the present paper this intention is fulfilled so far as I have been able, in view of the limited material at my command, and the difficulties of interpretation which now embarrass all students of fishes' brains.

The extent of these difficulties becomes apparent when I state that, since Gegenbaur has lent the weight of his high authority to Miklucho-Maclay's new interpretation of the parts commonly called cerebellum and optic lobes, *no region of the brain is clear as to its homology throughout the series of fish-like vertebrates.*

For the complete solution of these homological problems it is evident that simple and embryonic brains are primarily more useful than those of adults, or those which present peculiar characteristics. Hence I am availing myself of every opportunity for preparing and figuring, both as wholes and in sections, the brains of *Myxine*, *Petromyzon*, *Menobranchus* (or *Necturus*), and embryo sharks. But it is not likely that an embryo *Chimæra* will soon be available, and it seems hardly advisable to longer defer the publication of facts, some of which, at least, appear to be new and important, simply on account of doubts respecting the terms which should be employed for the designation of parts. Moreover, notwithstanding its special peculiarities, the brain of *Chimæra* presents certain features which may enable us to connect brain-forms which have hitherto failed to be reconciled with each other, or with the ideal, or typical brain, as now commonly accepted.

[1] Kindly placed at my disposal by Mr. Alexander Agassiz, Curator of the Museum of Comparative Zoology at Cambridge, Mass.

Again, as will be shown in the following historical sketch, the brain of *Chimæra* has not hitherto been accurately figured or fully described.

This fact alone would have led me to welcome an opportunity of adding to our knowledge of its structure; but an additional incentive lay in the consideration that the three species of *Chimæra*, with the single species of *Callorhynchus*[1] have always been regarded as peculiar, and not readily assignable to a place among the fish-like vertebrates.

In 1834 Johannes Müller (23, 74) united the two genera under the title Holocephala, regarding this group as an order of the class Pisces.

Some zoölogists have adopted Müller's view; but the Holocephala are often included with the sharks and skates under the name Selachians, or Elasmobranchiata.

So far as I am aware the structure of the brain has never been appealed to for the purpose of ascertaining the taxonomic relations of the Holocephala. I say the *structure*, because in the arrangement proposed by Mayer (5), little more than the external form of the brain seems to have been considered.

Historical Sketch.—So far as I am aware, the earliest account of the brain of *Chimæra* was by Valentin, in 1842. He states (1, 25) that his specimen was "well-preserved in alcohol;" but, judging from the figures, its condition was that of most fish-brains which are not exposed to the action of alcohol very soon after death of the animal. The principal features, however, are shown in so far as the brain was exposed; but it is evident from both the figure and description that only the hinder region of the brain was examined, and that Valentin failed to discover the olfactory lobes, the "hemispheres," and the greatly elongated mesothalamic crura, which are characteristic of this type of brain.

He does not state whether the brain was removed from the skull by himself. The channel connecting the hinder part of the brain-cavity with the front part is so narrow that the existence of

[1] Günther (19, viii. 349-352) recognizes the following species of *Chimæra*, viz.: *monstrosa*, coasts of Europe, Japan, Cape of Good Hope; *colliei*, west coast of North America; *affinis*, coast of Portugal. He also admits but a single species of *Callorhynchus*, *antarcticus*; but Duméril (29, 692) enumerates five. References are here made to a list of works at the close of this paper.

the latter might well be overlooked by an assistant. Still the general aspect of the regions examined by Valentin differs so much from that of any other entire brain that it is not easy to see how he could have stated his determinations without some qualification.

The short portions of the crura which were retained with the hinder regions of the brain, were regarded by Valentin as the olfactory nerves, and they are figured of considerable thickness, although in my specimen they are thin and ribbon-like. The rounded optic lobes he named hemispheres. The overhanging cerebellum was interpreted as the thalamus, or *lobus ventriculi tertii*, and the remaining parts as cerebellum and medulla. On pages 32 and 33 Valentin speaks of the cavity of the optic lobes ("Sehlappenhöhlung"), and designates it on fig. 4 (s) ; but neither the figures nor the description indicate distinctly the parts which he regarded as the optic lobes themselves; they must certainly have been very small in comparison with the supposed thalamus, since all the other conspicuous portions are otherwise interpreted.

Valentin's opinion as to the taxonomic significance of the brain is expressed in the following passage.

"Peculiar as the brain of *Chimæra* appears at first sight, it nevertheless proves to be intermediate between the brain of the Cyclostomes [Myzonts], on the one hand, and that of the Plagiostomes on the other." (1, 39.)

The following year, in his Report upon the progress of Anatomy (2), Johannes Müller commented as follows upon the paper of Valentin :—

"Of the brain of *Chimæra* we had before no figures, so that these by Valentin, with his description, supply a real deficiency. In the designation of the parts, however, and therefore also in the comparison with other brains, some things prove to be otherwise.

"The description and figures make it very probable that a part of the medulla oblongata is taken for the cerebellum. This remark of R. Wagner I find to be confirmed by the examination of a well-preserved specimen of the brain of *Chimæra*.

"What is called cerebellum belongs to the medulla, whilst that which the author calls 'the hammer-formed body' and compares with the lobus ventriculi tertii of Cyclostomes is the cerebellum.

The cerebellum and medulla with *Chimæra* closely resemble those of all genera of sharks whose brains are known to me."

"The brain of *Chimæra* has no resemblance to that of Cyclostomes, but much to that of sharks. Yet it differs greatly therefrom in the front part, because the optic lobes and the hemispheres are fused together, which is not the case with the sharks and skates. The olfactory nerves, as usual, enlarge behind the olfactory folds into a bulb. The small swelling from which they spring is the only representative of the great median masses of sharks which are probably the hemispheres."

I have been unable to find the observation of R. Wagner, above referred to, elsewhere recorded, but the foregoing passages lead me to infer that both he and Müller, like Valentin, believed the entire brain of *Chimæra* to be included in what was really only the posterior portion. It will be seen farther on that Gegenbaur attaches a different signification to Müller's remarks; but after careful re-examination of the passage I find myself obliged to adhere to the interpretation above offered.

In 1848, Busch published (3) figures of the brains of *Chimæra* and of *Callorhynchus;* the latter, however, represents only the posterior region. I am informed that a copy of this work has been obtained for the American Museum of Natural History in New York; but the library of which it forms a part has not yet (April, 1877) been placed upon shelves, and I have not been able to examine it.

These figures of Busch were reproduced in 1864 by Mayer (5). Like many other figures upon the plates of this author, the general aspect of these is good, but they are unsatisfactory in respect to details.

Mayer's description (5, 24, and 25) of these brains is in the form of a classification. The Holocephala are included under "Pisces Proëncephali," characterized as having "the olfactory lobe developed into an olfactory hemisphere or cerebrum." This group includes all the fish-like forms excepting the Teleosts which he designates (5, 27) as Pisces Mesencephali, the optic lobe being the hemisphere.

The brains of the Proëncephali are further characterized as follows: "The olfactory lobe is two to four times greater than the optic lobe, presents folds or lobes upon its upper surface, and in the middle two open lateral cavities with swellings within them."

"The optic lobe is small, spherical, without superficial commissure of the two hemispheres, or without *corpus callosum*,[1] and is separated from the olfactory hemisphere by an anterior prolongation of the *crus cerebri*. The basilar lobes [hypoaria ?] are little developed. The cerebellum varies in size, so as to form a series. There is a chiasma."

Mayer subdivides the "Proëncephali" into three suborders and includes the Chimæræ in the Macroëpiencephali corresponding with Selachians, or Plagiostomes and Holocephali. The characters are as follows: "The optic lobe contains a rudimentary ventricle, which is afterward united with the third ventricle, but no inner swellings. The chiasma is broad. The cerebellum consists of an anterior and posterior median mass and anterior and posterior convoluted lateral lobes more or less developed."

The "Macroëpiencephali" are subdivided into two families, the Raiæ or Skates, in which the hemisphere mass is "as broad as it is long;" and the sharks and Holocephali, in which it is an "elongated oval."

Finally, this "family" forms two groups, in one of which "the cerebellum is very large and covers part of the hemisphere," while in the other it "reaches only to the middle of the optic lobes." In this group are included, *Galeus canis*, *Scymnus lichia*, *Carcharias glaucus*, *Scyllium catulus*, *Scyllium borealis*, *Callorhynchus*, and *Chimæra monstrosa*.

In a note (p. 25) Mayer says, "The hemisphere is particularly slender and long in *Scymnus lichia* and *Chimæra*. Valentin's figure cannot be employed for a different interpretation of the parts. At any rate what Valentin calls the *lobus ventriculi tertii* is really the cerebellum."

The foregoing description indicates that Mayer's attention was directed chiefly to the form and general aspect of the brain, and that many of his determinations were based upon analogy rather than homology.

By implication Mayer ascribes lateral ventricles to all the Proëncephali; but he makes no special mention of them in the Holocephali, and neither the figures nor descriptions indicate the existence of the large "foramina of Monro," and the swellings therein which are described by me farther on.

[1] Alluding to certain structures, which he regards as representing the *corpus callosum*, with the Mesencephali.

The brains of Holocephala are not mentioned by Hollard, or Vulpian (4).

Owen copies (6, I, 276, fig. 179) Busch's figure of the brain of *Chimæra monstrosa*, and does not appear to have examined the brain itself. The olfactory lobes are united with the succeeding lobes (not separated as in Mayer's figure), and their necks appear to be connected by a thick transverse commissure, which has no existence; in the original figure this appearance may have been due to an unintentional exaggeration of shadow.

According to the plan of the work, the author's views of the Chimæroid brain are given in connection with his account of its separate divisions. The laminæ at the sides of the medulla are regarded (p. 276) as developments of the restiform columns. The optic lobes are mentioned (277) as smaller than either the cerebrum or cerebellum. The "cerebral crura" (called by me *mesothalamus*) are said (281) to "advance some way before they expand into the prosencephala." The latter are described (282) as "large, elongated, and smooth." On the same page it is said that neither the cerebellum nor the optic lobes are so large as the "prosencephalon;" but on page 288, the cerebellum is said to be "large."

In 1869, Gegenbaur published (8) an extract from a letter from Miklucho-Maclay relating to some peculiarities of the Chimæra's brain, adding remarks upon their morphological and taxonomic significance.

"The brain of *Chimæra*, as presented in the figures and description of Valentin, offers so many peculiarities that it was impossible to discuss it alone, or in connection with the other series of fish brain-forms.

"Miklucho found that the above-mentioned representation agreed in part with the results of his investigations of the brains of Selachians, but in other respects was wholly dissimilar. That representation showed a Zwischenhirn,[1] which is similar to that of Selachians. Valentin took it for the hemisphere. From it proceed a pair of swellings which were supposed to be the olfactory lobes. Then follows a portion corresponding to the Mittelhirn

[1] This is the common German term for the Thalamencephalon, or lobi ventriculi tertii; but Miklucho and Gegenbaur apply it, incorrectly, as I believe, to the optic lobes or Mittelhirn, and give this latter name to the cerebellum. This question will be discussed hereafter.

[really the cerebellum], which Valentin named Zwischenhirn; then a cerebellum with a medulla oblongata, which, interpreted as such by Valentin, present the characteristics of these parts with Selachians.

"So the greater part of the brain agrees with that of the Selachians, but where is the Vorderhirn?

"In Messina Herr Miklucho found the opportunity for investigation of the brain of *Chimæra*, and writes as follows: 'In the first place, I learn that the representation of Valentin is quite correct in some minor points. But the part which Valentin calls the olfactory tract, I ask myself, is not this the *Hirnstiele?* I extended the opening of the cranium, and, true enough, far forward lay the large and handsome hemispheres connected with the Zwischenhirn by elongated cerebral peduncles.'

"This Vorderhirn therefore corresponds to the part described by J. Müller (2) as the swelling of the olfactory nerves lying behind the olfactory folds. Since, moreover, there is a swelling which gives off olfactory nerves, there can be no doubt respecting the above-mentioned interpretation.

"The peculiarity of the Chimæra's brain consists, therefore, especially in the remarkable extension of the brain-stem, and the concomitant separation of the Vorderhirn from the Zwischenhirn. In the same degree in which the Vorderhirn is moved forward, the olfactory tracts are abbreviated, so that the swellings of the olfactory nerves are in contact with the Vorderhirn itself.

"The brain of *Chimæra* therefore resembles that of Selachians much more closely than was supposed by J. Müller, although the great similarity of the hinder regions was by no means unknown to him."

Gegenbaur does not mention the figures of Busch, which, like the copies of Mayer and Owen, present all the features whose discovery he seems to ascribe to Miklucho.

On the other hand he credits Müller with being acquainted with the existence of these parts. As already stated, I cannot find, in Müller's remarks, any evidence of such knowledge. On the contrary, he distinctly says that "the lobi-optici and lobi-hemisphærici are closely united."

Miklucho-Maclay, in 1868 and 1870, published two papers (7 and 10) upon the brains of fishes, but in neither do I find any reference to the brain of *Chimæra*.

The paper of Panceri and de Sanctis (9) is known to me only through a brief abstract in the Zoological Record for 1872, p. 86. It does not appear to treat especially of the brains of the Holocephala.

Duméril, who describes (21, I, 65–73, pl. 2) somewhat at length, though apparently not from original investigations, the brains of Plagiostomes, makes no reference to those of Holocephala; neither are they alluded to in the Manuals of Van der Hoeven or Rolleston.

In 1871, Huxley included the Holocephala among the Elasmobranchs, and left it to be inferred (13, 118) that their brains resemble those of sharks and skates.

More recently, in his paper (16) upon the brain, the skull, and the pectoral fins of *Ceratodus*, Huxley makes some very suggestive remarks (pp. 30, 41, 45, 57) concerning the taxonomic relations of *Chimæra.* These will be referred to hereafter. I do not see, however, that he anywhere implies that the brain differs essentially from the plagiostome type, and in the summary (p. 41) of the characters upon which he is inclined to base the opinion that the Holocephala should be regarded as a primary subdivision of fishes, the brain is not even mentioned.[1]

In April, 1876, the following note was added while my paper on the brains of N. A. Ganoids (17) was passing through the press:

"Just as this goes to press I am enabled, through the kindness of Mr. Alex. Agassiz, to expose and examine the brain of a well-preserved male *Chimæra* in the Museum of Comparative Zoology. The cerebellum is very large and covers the optic lobes, but is not folded transversely as in most, if not all, adult sharks and skates. The crura thalami are very long and thin, and united ventrally by a delicate membrane, apparently only pia mater. Anteriorly each crus expands into a prothalamus, the dorsal border of which is thin and slightly everted. This prothalamus, however, instead of forming the principal anterior mass as in Ganoids, is overlapped outside by a large and elongated hemisphere about 8 mm. in height and 15 mm. in length. On the hinder third of the mesial surface is a large rounded foramen of Monro, 4 mm. in diameter. The lateral ventricle extends forward into the olfactory

[1] This paper was known to me only through a brief abstract in "Nature" for Jan. 6th, 1876, until Nov. 1876, when a copy was kindly loaned to me by Prof. S. F. Baird.

lobe. Into the foramen, and occupying its entire area, projects a thickening of the outer wall of the hemisphere which may represent a primordial corpus striatum. Just in front of the foramen the ventral borders of the hemispheres are connected by a transverse commissure. I greatly regret not having been able to examine this brain before presenting this paper. It seems to furnish an actual form intermediate between the apparently distinct types represented by the brains of Selachians, Ganoids, and Dipnoans. If I correctly interpret the appearance of a partial subdivision of the elongated mass behind the olfactory lobe, the Chimæra's brain presents a more equal proportion of hemisphere and prothalamus than exists in Ganoids or Teleosts, where the former seems to be reduced to a rudiment hardly recognizable as such."

Remarks to the same effect were made before the Academy on the 4th of April, as already mentioned.

The brain itself, with most of the drawings here published, was exhibited and remarked upon by me at the meeting of the American Association for Advancement of Science, Aug. 25th, 1876, in connection with a paper on the brains of certain fish-like vertebrates (24).

Prof. Huxley's comments (25) upon that paper referred mainly to the question of the homology of the optic lobes and cerebellum of Selachians, which will be more fully discussed hereafter.

The general aspect of the Brain of Chimæra.—The brain of the adult[1] *Chimæra* presents three regions of nearly equal length, viz., a complex high mass behind, a pair of elongated masses in front, and an intervening pair of slender bands.

The height and complexity of the hinder mass remind one of the corresponding region with sharks and skates. In general form, the anterior masses resemble the hemispheres of Dipnoans; but the slightness of their union by a transverse commissure is a characteristic of Ganoids and Teleosts; while the length of the crura, and the size and position of an orifice upon the mesial surface of each anterior mass are features not hitherto observed, so far as I know, in the brain of any other fish-like vertebrate.

In general, therefore, it may be said that the brain of *Chimæra*

[1] From analogy we may infer that in very young examples the interval between the anterior and posterior regions is much less; also that the lobes of the medulla are less folded, and the cerebellum smaller.

presents certain features peculiar to itself; it also combines features more or less characteristic of the brains of Ganoids and Plagiostomes. The significance of these resemblances will be considered farther on.

THE TYPICAL BRAIN.—Notwithstanding great differences in the relative size and complexity of the principal subdivisions, and in the number of the accessory parts, the brains of all Mammals, Birds, Reptiles, and Batrachians may be referred to a single type. The reduction to this type may be made either by comparing many forms as intermediate stages of an ideal transition, or by tracing back the development of the brain of a single form to its earliest and simplest condition.

Among the remaining groups of fish-like vertebrates the lamprey eels (Petromyzontidæ) seem to possess brains closely resembling those of Batrachians. The Myxinoid brain has not yet been satisfactorily homologized with that of *Petromyzon*, but may prove to be a degenerated form thereof. As figured by Owen (20, and 6, I, fig. 186, p. 282), the brain of *Protopterus* seems to closely resemble that of the tailed Batrachians; but Huxley (16, 30) finds in *Ceratodus* (which is regarded as a Dipnoan) a feature which is characteristic of the plagiostome brain, so that the matter is still in doubt. The brains of Ganoids, and Teleosts, and Plagiostomes are not yet satisfactorily homologized with the typical brain; the same is the case with the Holocephala (17).

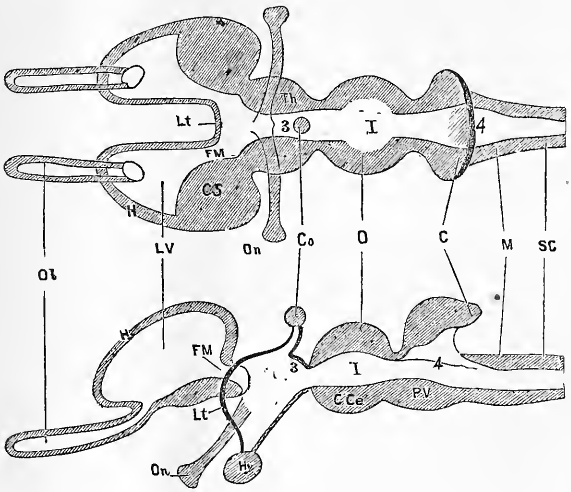
The typical brain comprises the following parts: *Medulla* and *fourth ventricle; Cerebellum* with its *ventricle; Optic lobes* with their *ventricles; Thalami*, with the *third ventricle*, *the conarium* above, and *hypophysis* below; *Hemispheres*, containing the *lateral* (first and second) *ventricles*, which communicate with the third through the *foramina* of *Monro; Olfactory lobes* with their *ventricles.*

Thickenings of the lower or outer walls of the hemispheres constitute the *corpora striata;* and these are joined by the *anterior commissure* which is a specialization of the anterior boundary of the third ventricle, the *lamina terminalis.*

The thalami are united posteriorly by the *posterior commissure*, and between their central portions may be formed the *middle* or *soft commissure.* The *fornix* seems to result from a thickening of the vertical fibres of the lamina terminalis in front of and

above each foramen of Monro, and from the subsequent union of the two series of fibres across the median line.

The *pons Varolii* is a band of transverse fibres upon the ventral side of the medulla, connecting the lateral regions of the cerebellum. The *corpus callosum* is a transverse commissure uniting the contiguous faces of the hemispheres. The corpus callosum and the pons Varolii seem to be confined to the mammals.



Diagrams (slightly altered from Huxley) represeuting the type of vertebrate brain. *S C*, spinal cord; *M*, medulla oblongata; 4, fourth ventricle; *O*, optic lobes; *I*, optic ventricle, or iter a tertio ad ventriculum quartum; *C Ce*, crura cerebri; 3, third ventricle; *Th*, thalami; *Co*, conarium; *On*, optic nerve; *F M*, foramen of Monro; *L V*, lateral ventricle; *H*, hemisphere; *C S*, corpus striatum; *Ol*, olfactory lobe; *Hy*, hypophysis.

Figures and descriptions of the typical brain are given by Huxley (13, 56–59); his figures were reproduced by me with slight modifications in a former paper (17, plate 3), and they are herewith presented again from a conviction that an understanding of it, and of the brains of Amphibia which most nearly embody the type, is essential to the successful study of the many and complex modifications which exist among the other vertebrates.

Enumeration of Parts.—Accepting, provisionally, the type of vertebrate brain as figured and described by Huxley, it is desirable to ascertain how far its subdivisions are recognizable in the brain of *Chimæra*.

Respecting the following parts there can be no doubt: The

spinal cord ($S\ C$), the optic nerves ($o\ n$), and chiasma ($o\ c$), and the olfactory lobes (Ol).[1]

But none of the intermediate regions have yet been determined satisfactorily as to their limits, and as to their correspondence with the subdivisions of the typical brain.

The cerebellum lies between the medulla behind, and the optic lobes in front. If the cerebellum, therefore, can be determined the other two parts will naturally follow.

The existence of a cerebellum is doubtful in the Myxinoids, and among the other fishes it presents very great diversities of size, form, and complexity. Thus in *Petromyzon* and the Dipnoans it is a narrow bridge; in *Lepidosteus* it is an inflated vesicle; in *Morrhua* it is retroverted, in *Pimelodus* anteverted. In skates, that which has been usually regarded as the cerebellum is a somewhat elongated and flattened mass which is distinctly single and median, although it may present a longitudinal median furrow. With many sharks this part is deeply furrowed transversely as in birds.

Prior to the year 1868, so far as I know, this region of the plagiostome brain was universally recognized as the cerebellum. But Miklucho-Maclay (7 and 10) has proposed to call this the *Mittelhirn* (optic lobes), and to restrict the term cerebellum to a narrow band (figs. 2 and 8, c′) between it and the medulla. The region commonly called optic lobes he names *Zwischenhirn* (thalami).[2]

Now there is certainly some ground for this view. The transverse lamina of sharks and skates is apparently identical with

[1] For obvious reasons the determinations of Valentin are not here considered.

[2] I feel constrained to protest against the introduction of the terms Vorder-hirn, Zwischen-hirn, Mittel-hirn, Hinter-hirn, and Nach-hirn, and of their English equivalents fore-brain, etc. If the conventional and universally understood terms medulla, cerebellum, etc., are to be discarded for descriptive names derived from one modern language, what is to prevent the anatomists of Spain, or Russia, or any other country from employing other descriptive titles derived from their own languages? Such substitutions would soon cause morphological science to revert to the chaotic condition in which descriptive zoölogy was found by Linnæus.

The region designated by thalami has already received the following names: Zwischen-hirn, between-brain, inter-brain, diencephalon, deutencephalon, lobus ventriculi tertii.

the visible cerebellum of Amphibia, Myzonts, and Dipnoans; it seems to represent the simple and primordial form of the organ. Nor is it easy to account for the sudden interpolation between it and the optic lobes of the greatly expanded or inflated mass commonly called cerebellum in other vertebrates.

But it is worth bearing in mind that, with some Ganoids, as *Acipenser*, and *Lepidosteus* (Wilder, 17, 181, fig. 7), the anterior border of the apparently simple cerebellum is continued forward into the cavity of the optic lobes. Why then may we not imagine that an eversion of this fold has given rise to the inflated or convoluted mass of sharks and skates? This would give us two distinct portions of the cerebellum; the posterior lamina, and the anterior vesicle.

To Maclay's interpretation assent has been given by Gegenbaur (12, 549; 14, 524). But neither of these anatomists has as yet published facts or arguments which warrant the abandonment of the older view, while several others have questioned the validity of their conclusions. Amongst these are Jackson and Clarke (15, 77); Balfour (26, 560); Huxley (16, 31–25); and myself (17, 172, and 24). In a letter to me, Prof. Rolleston has also expressed his non-acceptance of Maclay's view.

In his paper on *Ceratodus* (16, 31) Prof. Huxley says: "I cannot accept the views of Miklucho-Maclay, whose proposal to alter the nomenclature of the parts of the Elasmobranch's brain appears to me to be based upon a misapprehension of the facts of development."

My argument (24) against the view of Maclay was based upon the fact that in the brain of a large shark (*Carcharias obscurus*) the fibres of the optic tracts are distinctly traceable to the optic lobes and the thalami, and not at all to the cerebellum as should be the case if the cerebellum be really the optic lobes.

In commenting upon the paper just mentioned, Prof. Huxley (25) repeated the opinion expressed in the paper on *Ceratodus*, and called attention to the fact that wherever the fourth nerve (trochlearis or patheticus) has been identified among vertebrates, its apparent origin has invariably been between the optic lobes and the cerebellum. This point seems to have been considered by J. Müller,[1] and it is briefly discussed by Maclay and Gegenbaur,

[1] Vergl. neurologie der Myxinoiden, 1838, p. 215.

who, however, regard it as not constituting an insuperable objection.

There is one other consideration which appears to have been overlooked hitherto. Among the air-breathing vertebrates, from frog to man, the roof of the optic ventricle is complete, while that of the third ventricle is only partial. Posteriorly the dorsal borders are united by the posterior commissure, but anteriorly the true nervous tissue is absent, and the ventricle is covered only by the lining membrane and the overlying pia mater. According to the new interpretation, the thalami of fishes lack the feature which characterizes them throughout the series of air-breathing vertebrates, and assume the peculiarities of the optic lobes.

Should Maclay and Gegenbaur insist upon the correctness of their interpretation, the matter will need to be treated in full hereafter; but as, for obvious reasons, the material for its elucidation must be derived from sharks and skates rather than from *Chimæra*, I trust that in adhering in the present paper to the commonly accepted view I shall not be held to disregard the earnestness of Maclay, or the high authority of his distinguished teacher.

For reasons which will be presented farther on, I have designated the parts between the optic and the olfactory lobes as follows: the slender bands as the *mesothalamus;* their posterior enlargements as the *basithalamus;* their anterior enlargements as the *prothalami;* and the remainder of the elongated mass on each side which incloses a ventricle, as *hemisphere.*

The Spinal Cord (S C).—For at least 3 cm. behind the medulla the cord[1] is of uniform size and shape. Its greatest transverse diameter is 4 mm., and its vertical diameter 3 mm. As seen in the cross-section (fig. 22), its greatest width is ventrad of the centre, and the sides of the ventral median fissure (*v*) slope outward more gradually than those of the dorsal (*d*).

The nerves have been separated from the cord, but along the dorsal lateral line (fig. 1, *d l*) is a series of slight elevations about 2 mm. apart, which may indicate the points of origin of the dorsal roots of the spinal nerves; the ventral lateral line (fig. 4, *v l*) presents no such elevations. The lateral tract (*l c*) between the dorsal and ventral lateral lines is slightly elevated above the dorsal and ventral tracts (*d c* and *v c*), and, when first exposed, presented a darker color which disappeared in a few days.

[1] The remainder of the cord was not exposed.

The structure of the cord, and the homologies of its parts with those of the human spinal cord, should be determined by microscopic sections of better preserved specimens.

The Medulla Oblongata.—The medulla consists of two parts, the *medulla proper* or continuation of the spinal cord, and two pairs of lobes which may be provisionally called *dorsal* and *lateral*.

The medulla may be said to commence at a point about 4 mm. behind the posterior end of the lobes, and about 3 mm. behind the angle of the fourth ventricle. At this point the cord begins to change its form and to increase in size.

The dorsal border preserves nearly the same direction as that of the cord itself, but the ventral border inclines ventrad, so that just behind the lobes the dorso-ventral diameter is 4 mm. At a point 4 mm. farther forward the ventral border is 2 mm. lower than the ventral border of the cord, and it remains at this level until suddenly deflected ventrad beneath the cerebellum.

The width of the medulla also increases so as to be about 6 mm. just behind the lobes. In front of this point the width becomes about 8 mm., on account of the prominent lateral lobes.

The dorsal lateral line (*d l*) begins to be deflected downward at the point of transition from the cord to the medulla; but its deflection is more rapid than that of the ventral border; the dorsal tract (*d c*) not only increases in width, but is slightly elevated above the lateral column. The distinctness of the dorsal lateral line (*d l*) ceases just in front of the posterior end of the lateral lobe, but the elevated ventral margin of the lobe follows the same general direction. The slight elevations which indicate this line upon the cord do not appear upon the medulla. The ventral lateral line (*v l*) gradually disappears at about the middle of the length of the medulla, as seen in fig. 4; the ventral median furrow (*v*) ends rather abruptly just behind the downward deflection of the ventral surface under the cerebellum; it does not present the bifurcation which is figured by Valentin, 1, fig. 3, *F*.

The dorsal fissure (*d*) widens into the fourth ventricle about 3 mm. in front of the point where the enlargement of the medulla begins, and about 1 mm. behind the superjacent dorsal lobes. The posterior angle of the ventricle is covered by the ligula (fig. 3, *l*.)

The fourth ventricle is quite long, but, as seen in figs. 19–22, its cavity is nearly obliterated by the development of its various walls. The hinder part of the floor presents three rounded tracts

upon each side. Suggestions as to the homologies of these tracts are offered by Jackson and Clarke (15, 79), but I refrain from doing more than indicate their appearance and relative position.

Close to the median line is a rounded tract (*m t*), which is traceable anteriorly to the cerebellum; it is about 0.7 mm. in diameter. Just outside of the posterior half of this is a depressed triangular surface, the exposed border of an intermediate tract (*i t*). Outside of this, and apparently the forward continuation of the posterior border of the fourth ventricle, is a tract (*n t*) of which the mesial border, projecting over the intermediate tract, presents a series of transverse furrows with intervening nodules, on account of which I have called it the *nodular tract.* It is apparently what Owen (6, I, 273) calls the "vagal tract." The whole extent of these parts can only be seen after raising the lateral lobe, which may be done without, apparently, causing a rupture of fibres, although the attachment is quite intimate. It is then seen, as in fig. 19, that the four nodules are ganglia of origin of as many nerve roots, which, however, do not in this example project beyond the surface of the medulla.

As already stated, the lobes of the medulla are two pairs, *lateral* and *dorsal.* (See figs. 1, 2, 3, 20, 21.) These terms are here employed in a descriptive sense. The lobes may perhaps be homologized with parts of the medulla of man and of other vertebrates, but the interpretations of Owen and Valentin do not wholly coincide, and I forbear adding to the synonymy until the structure and development of these lobes have been examined among the sharks and skates; *Torpedo* and its allies would probably be very instructive.

The lateral lobe (*l l*) seems to be an enlarged continuation of the dorsal tract of the cord. Its dorsal surface is in contact with the ventral border of the dorsal lobe.

The outer surface of the dorsal lobe is somewhat rough, and, as seen from the side or from the mesial surface, presents the form of an elongated triangle with its apex backward; seen from above the apex appears rounded. The mesial surface is vertical, and closely applied against that of its lateral homologue.

As seen in fig. 20, the posterior portion of the dorsal lobe is wholly separate from the lateral lobe and the medulla; but a section farther forward, as in fig. 21, shows a line of union between its ventral margin and the mesial border of the lateral lobe.

Anteriorly, both the dorsal and the lateral lobes develop a series of folds (*d m′* and *l′*), which are continuous with each other, and through the transverse lamina (*c′*) with the cerebellum.

These folds are so complex that a complete description would be very long and difficult to follow; it seems better, therefore, to wait until their type can be ascertained from a young brain, or from comparison of the parts with those of sharks and skates.

THE CEREBELLUM (C and *c′*).—As with most Plagiostomes the cerebellum of *Chimæra* consists of two quite distinct portions, an anterior and a posterior. The anterior is a prominent inflated mass (C), the posterior is a transverse lamina (*c′*) which lies behind the other, and is only visible after dissection, as in figures 2 and 8. This posterior cerebellum is what Maclay regards as representing the entire organ, the anterior inflated portion being, in his opinion, the optic lobes.

As already intimated (page 231), the lamina may prove to be the true homologue of the simple cerebellum of Amphibia, Dipnoa, and Myzonts. Its position is well shown by Valentin (1, fig. iv. *i*), but his figure does not present one peculiarity: just upon the median line the thickness of the lamina becomes greatly diminished, as shown in my figures 2 and 8.

The anterior cerebellum (C) is an inflated oval mass resting upon the medullary lobes behind and the optic lobes in front. As seen from the side the short handle of the "hammer-formed body" is formed by upright crura (*c*), which join the base of the brain at nearly a right angle.

This portion of the base of the brain (*c c*) presents no peculiarities to distinguish it from the regions immediately in front and behind. The exposed surfaces are rounded and smooth; there is no sign of a transverse ventral commissure, or *pons Varolii.* The ventral outline of the base of the brain changes its direction at this point, and, as seen in fig. 2, its vertical thickness diminishes rapidly as it extends forward beneath the optic lobes.

The crus or peduncle of the cerebellum (*c*) measures about 3 mm. in antero-posterior width, and is 4.5 mm. high. Its hinder border is slightly overlapped by the anterior lamina of the lateral lobe. In this alcoholic specimen the exposed surface of the peduncle readily detached itself as a lamina thickest in the centre and thinner at all the borders; the plane of separation is indi-

cated by the line upon the section represented in fig. 8. The surface exposed by the detachment of the lamina is irregular.

As shown in the horizontal section (fig. 8), and the median vertical section (fig. 2), the peduncle of the cerebellum consists of an anterior and a posterior vertical lamina, which are in close apposition, and continuous by their outer borders. The anterior lamina is 2 mm. in thickness at its junction with the horizontal portion or cerebellum proper, but below becomes very thin, forming a sort of "valve of Vieussens," which is continuous with the hinder border of the optic lobes. The posterior lamina is more complex. On the middle line it is very thin; the cut surface of this median thin portion is shown in fig. 2. But on each side of the middle line it becomes suddenly very thick, as is best seen in fig. 8 (*c p*). Posteriorly the lamina becomes continuous with the vertical lamina (c'), which Maclay regards as representing the entire cerebellum.

Upon the exposed surface the dorsal limit of the peduncle is indicated by a curved line with its concavity looking ventrad; this also marks the line of separation of the superficial lamina already referred to.

Dorsad and in front of this is a second furrow which extends obliquely dorsad and backward from the ventral border of the cerebellum. Excepting these, and the median furrow to be presently described, the exposed surfaces of the cerebellum and its peduncles are smooth.

The expanded portion of the cerebellum is 13.5 mm. in length; about 8 mm. lie in front of the centre of the peduncle. The anterior portion also has a slight downward inclination, so that, to employ Valentin's comparison, the posterior portion is the striking part of the hammer, and the anterior is the claw.

The greatest width of the cerebellum (7.5 mm.) is just over its peduncle; it tapers quite regularly to an obtuse point before and behind, giving the whole an oval outline. Seen directly from above the posterior extremity is the sharper; but when the brain is tilted backward, as in fig. 5, the anterior extremity is more pointed.

The dorsal aspect of the cerebellum presents a median longitudinal furrow, 5.5 mm. long. Its centre lies over the centre of the peduncle. In Valentin's figure the furrow extends nearly the entire length of the cerebellum.

The ventricle of the cerebellum (*c v*) has the same general form as the organ itself, as shown in the median section (fig. 2), the transverse section (fig. 10), and the horizontal section (fig. 11).

The cerebellum of *Chimæra* presents some interesting features. It is large and its walls are thick, yet its form is simple, while those of many sharks and skates, in the adult state, are much folded. The median furrow occurs in some Plagiostomes, but is a rare feature of the cerebellum of other vertebrates.

THE OPTIC LOBES (O).—Reference has already been made (p. 230) to the view of Maclay and Gegenbaur respecting the nomenclature of these parts.

As is usually the case the form of the optic lobes is quite simple. Their size is moderate, and when the brain is viewed from above they are wholly concealed by the overhanging anterior portion of the cerebellum, as shown in figs. 1 and 3. In fig. 5 the parts are seen from above and in front so as to expose the optic lobes. The difference between the outline of the lobes in figs. 5 and 6 is thus accounted for.

The optic lobes are borne upon the crura cerebri (*c c*) already described as forming an obtuse angle with the medulla. The outer surface of each crus presents a distinct rounded elevation or protuberance (*t*), rather nearer the ventral than the dorsal border. It is shown, somewhat exaggerated, by Valentin (1, figs. 1 and 3), and called by him "*tuber cruris cerebri*."

Measured in the direction of their greatest length, nearly parallel with the crus, the optic lobes are 8 mm. long; taken together, their greatest transverse diameter is 7 mm., which is reduced to 3.5 mm. near their hinder and more rounded end, and to 2.5 mm. near their front and compressed extremity. The median furrow, which marks the division into two lateral lobes, extends their whole length. The size and form of the ventricles and the thickness of different parts of the walls are shown by the sections represented in figures 2, 8, and 9. The cavity is smaller than in the brains of many other fishes, but not, as with mammals, contracted into an "aqueduct of Sylvius."

As seen in fig. 9 the ventricle presents four well-marked regions: two median, the upper broad and the lower narrow; and two lateral, and compressed, one upon each side, extending upward and slightly outward into the elevations upon each side of the median furrow. The lower compressed portion of the ventricle

is wider behind and in front than at the middle; hence the sides may be not improperly called the lobes of the optic ventricle (figs. 2 and 9, *o v l*). But these swellings are not necessarily to be regarded as homologous with the thickenings or involutions of the posterior walls in some Reptiles and Amphibia.

The parts already described constitute a series of median masses which may, without difficulty, be regarded as formed by the modification of a corresponding number of primary cerebral vesicles. But it is not so easy to understand how the remaining portions of the Chimæra's brain have been developed from the single anterior vesicle which, with birds and mammals, has been found to give rise to all the parts in front of the optic lobes.

These parts are the *thalami*, the *hemispheres*, and the *olfactory lobes*.

Could we trace the development of the Chimæra's brain, or had we full acquaintance with the brains of all living Plagiostomes, and of some apparently transitional fossil forms, it is probable that little difficulty would be experienced in assigning the proper limitations and names to these parts. At present our determinations and nomenclature must be largely provisional.

Concerning one pair of lobes, however, there can be very little doubt, so that it may be well to commence with them.

The Olfactory Lobes (O l).—These parts, whatever their size or form, have always been identified among vertebrates by one or both of two criteria: their continuity, either direct or by crura, with the hemispheres behind; and their connection, through the olfactory nerves, with the nasal cavities in front.

In *Chimæra* the nasal cavities receive numerous nerves from the anterior surface of the most anterior pair of lobes, which may therefore be called the *olfactory lobes*.

Each lobe is a sub-quadrate mass, about 7 mm. high, and 4 mm. both in width and in its greatest antero-posterior dimension. Its junction with the hemisphere is marked by a decided constriction, which becomes a cleft at the ventral border.

With this alcoholic specimen the lobe may be readily detached from the hemisphere in a plane which is, at first, a continuation of the cleft dorsad and forward, but becomes nearly vertical at about the middle of the height of the lobe. The two facets thus exposed are slightly sunken below the border of the lobe. At about the centre of the dorsal facet is a very slight circular de-

pression (fig. 16, *o l v*); this coincides with the anterior extremity of the lateral ventricle (figs. 12, 14, 18, *l v*), and may therefore be regarded as a very rudimentary olfactory ventricle.

The mesial surface of the olfactory lobe is flat, and continuous with that of the hemisphere. The outer surface has less antero-posterior extent, because the anterior surface looks obliquely outward. The outer surface is rounded, there being a very decided depression between its most prominent portion and the most anterior elevation of the hemisphere.

The anterior surface is not only oblique, as above stated, but also divided into three distinct regions, as shown in figs. 12 and 17. The dorsal and ventral regions are nearly circular, though the transverse diameters are slightly greater than the vertical, and covered by the filaments of the olfactory nerves. Between them is a narrow, depressed area, which is devoid of these filaments. The olfactory lobes are wholly distinct from each other.

The Hemispheres (H).—The parts called hemispheres with man, birds, reptiles, and batrachians have the following features, constant and common to all: 1. They are lateral masses. 2. They contain each a lateral ventricle, which communicates posteriorly with the median third ventricle through a "foramen of Monro." 3. They have no direct nerve prolongations, being connected only with the thalami behind, and the olfactory lobes in front. 4. The posterior extremities of their mesial walls are united by the anterior wall of the third ventricle—the *lamina terminalis*.

Of these four characters the first three certainly apply to the anterior three-fourths of the elongated mass, which, with *Chimæra*, lies just behind each olfactory lobe; but respecting the fourth character some qualification may be required. According to the second and fourth tests the posterior fourth of the mass cannot be regarded as a true hemisphere; the same is the case with the whole of the second pair of lobes, with Ganoids and many Teleosts, which have been usually called hemispheres, but which contain no lateral ventricle, and have, therefore, no true mesial wall.

To these pseudo-hemispheres, I have given the name *prothalami* (17, 179); and the same term may be applied to the posterior fourth of the elongated lobes of the Chimæra's brain.

Strictly speaking, the term prothalamus should be applied to

the region as a whole; each lateral moiety would then be a *hemi-prothalamus*. But the shorter word may generally be used without the risk of misconception.

The length of each lobe is about 11 mm.; its height is 6 mm., and its greatest thickness 4 mm.

I am unable to determine the precise boundary line between the prothalamus and the true hemisphere. The external surface is divided by two transverse depressions into three elevated regions, of which the middle is the larger. The hindermost elevation may be said to correspond with the prothalamus.

The mesial surface presents three features which, so far as I know, have never been described—an aperture, an elevation, and a commissure. The region occupied by these corresponds very nearly with the middle elevation upon the outer surface; see figs. 1, 2, 13, 14, and 15.

The commissure is designated as *l t* upon figs. 13 and 14, but upon fig. 2 it is not marked at all. It is a flat fibrous band connecting the mesial surfaces of the two hemispheres. It was torn during the extraction of the brain, but appears to be about 3 mm. wide at its middle, and nearly twice as wide at either end. Its thickness is about 0.5 mm., the anterior and posterior borders being distinct and rounded. Its plane is slightly oblique, the anterior margin of the attachment being near the middle of the height of the hemisphere, about 4 mm. behind the olfactory suture, while the posterior margin is near the lower border. It seems safe to conclude that this commissure represents a remnant of the primitive lamina terminalis, but I am not prepared to say that it corresponds to the anterior commissure of higher vertebrates. It may be homologous with the commissure of the prothalamus in *Lepidosteus*, figured by me in 17, plate 2, but its relations to the foramen of Monro are not the same, as will now appear.

The foramen or aperture already referred to is the posterior termination of the lateral ventricle. From the section shown in fig. 15 it is seen that near the anterior termination, at the olfactory lobe, the inner and outer walls are of nearly equal thickness. But the cavity gradually approaches the mesial surface, and opens thereon about 7 mm. from the olfactory suture. This orifice forms a semicircle; the extremities are one above the other, and 4 mm. apart. The margin is distinct and rounded, though thin. The commissure is continuous with the ventral margin, but extends

2.5 mm. in front of it, and about 1 mm. behind it. The dorsal margin is continued backward and downward as a slight ridge upon the mesial surface of the prothalamus near the dorsal border.

There can be no doubt that this aperture corresponds to the foramen of Monro, or passage from the median to a lateral ventricle, but it is not easy to understand how the commissure, a part of the lamina terminalis, can extend so far in front of it.

Into the space which is nearly circumscribed by the margins of the foramen and its posterior continuations there projects a smooth convex surface, which is designated as *x* on figs. 2, 13, and 15. Its posterior border is semicircular, and a deep furrow separates it from the mesial surface of the prothalamus. Anteriorly it is continuous with the outer wall of the lateral ventricle, as shown in fig. 15. As suggested in a previous paper (17, 183, note 31), since this surface indicates a thickening of the outer wall of the ventricle, the thickening itself may be a primordial *corpus striatum*, but I hesitate to employ the term at present and would prefer to designate it as the *corpus innominatum*.

THE THALAMENCEPHALON (T).—This is the general name for all the region between the hemispheres in front, and the optic lobes behind. In most brains it is comparatively short, and presents no very characteristic features; but its extreme length forms the most obvious peculiarity of the Chimæra's brain.

With adult mammalia the region includes two irregular masses, the thalami, between which is the third ventricle; the conarium is above and the hypophysis below. With *Chimæra* the thalami themselves form three distinct regions, posterior, middle, and anterior, which I have named *basithalamus*, *mesothalamus*, and *prothalamus*.

The prothalamus. This region has already been described in connection with the hemispheres with which the two prothalami are continuous. There is reason for believing that this region exists in all vertebrate brains, and is very extensive in certain forms. This idea will be again presented at the close of this paper. I pass now to the intermediate region of the thalamencephalon.

The *mesothalamus* (*c t*). In my description of the brain of *Lepidosteus* (17, 179) this region of the brain was called *crura thalami;* the new term is to be preferred.

The mesothalamus consists of two narrow bands about 16 mm.

long, and 2 mm. in vertical diameter; their thickness is about 0.5 mm. Their dorsal and ventral borders are slightly thicker than the intermediate portion, and are inclined slightly toward the middle line so that the inner surfaces are concave, the outer convex.

The two bands may have been united by a thin ependyma, but so far as regards true nervous tissue they are separate in their entire length. Their hinder extremities arise quite abruptly from the basithalamus. Anteriorly, the mesial concavity becomes greater, but at the same time, the dorsal border presents a thinner edge which is turned *outward*. Then each band becomes continuous with the corresponding prothalamus.

The basithalamus (*b t*). This name is given to the depressed and constricted part just in front of the optic lobes, of which it forms a kind of neck. It may be said to be bounded by two imaginary lines, the one passing just in front of the optic lobes and the protuberance upon the underlying crus, the other passing from the most anterior border of the optic lobe in front of the chiasma. The triangular outer surface thus bounded represents the optic tract, the expanded nerve passing upward and backward to the optic lobe of each side. The basithalamus seems to correspond to the hinder part of the thalami with air-breathing vertebrates.

The cavity of the basithalamus is a slender rounded canal, the forward continuation of the optic ventricle. Anteriorly this canal curves upward, and opens through the foramen of the thalamus (fig. 5), just above the chiasma. This foramen is not rounded, but quadrangular, the angles projecting vertically and laterally. From above the orifice is concealed by a pair of thin horizontal plates (figs. 1, 2, 5, *t l*) which are attached to the anterior border of the optic lobes, and united by the posterior fourths of their mesial borders. This double cover is not represented by Valentin, and seems not to have been noticed in the brains of other fishes; but I have found it, under one form or another, in all ganoid, teleost, and plagiostome brains so far examined. It seems to be the reduced representative of the posterior part of the roof of the third ventricle with Amphibia and Myzonts; if so, we should name it *posterior commissure*.

The conarium. With Amphibia this part lies just above the foramen, closing it, in fact; still it not infrequently is removed

with the roof of the brain cavity; with most Plagiostomes it is in close contact with the roof, and this was probably the case with *Chimæra*, since the conarium of this example is wanting. A depressed quadrangular space is left upon the median line between the contiguous margins of the optic lobes and the cover above described.

The hypoaria (*h*). As seen in figures 1, 2, and 4, beneath the basithalamus is a rounded mass, consisting of a pair of oval lobes, with a triangular median surface between their hinder portions. These are apparently the parts called by authors *hypoaria*, or *lobi inferiores;* they may correspond to the *tuber cinereum* of anthropotomy, but the homology of the parts of this region of the brain is not yet well determined.

Each lobe is about 6 mm. long, and about 4 mm. wide. They are hollow; their cavities communicate with each other, and, through a vertical passage, with the ventricle of the basithalamus. On the median line the triangular space between the hinder portions of the lobes presents a fissure about 3 mm. long, by which the cavity of the hypoaria opens externally.

Below the corresponding fissure in the brains of *Lepidosteus* and other fishes is a globular mass, apparently vascular, which may represent the hypophysis. No such mass was found in this specimen, but it may have been lost through inadvertence. As above intimated, the homology of these parts is not yet understood.

The optic nerves (*o n*) are about 1 mm. in diameter, excepting just before their union to form the chiasma; here they increase in width, and then become constricted. The dorsal borders of the enlargements are slightly overlapped by the mesothalami.

The *optic chiasma* (*o c*) is very compact; but I have not examined its structure.

Morphological Considerations.—Whatever may be the peculiarities of the hinder regions of the brain of *Chimæra*, there appears to be a close homology between them and the hinder regions of the brains of most sharks and skates; the latter, therefore, as more accessible, should be employed for the determination of the structure, and mode of development of the medulla, cerebellum, and optic lobes.

But the ordinary Plagiostome brain seems to throw no light upon the study of the remaining divisions of the chimæroid brain,

and some features of the latter seem to be exaggerations of the characters of certain Ganoids. In the brain of *Scymnus lichia*, however, as figured by Mayer (5, taf. 1, fig. 7), there are indications of a transition between the plagiostome and chimæroid types, and I would urge upon any anatomist who may have the opportunity, the need of a careful examination of its brain. Still more desirable is the discovery of very young examples of *Chimæra*.

I think that I begin to see, though still dimly and imperfectly, the method by which the close homology of the parts in front of the optic lobes can be demonstrated.

The first, and most essential, step in this demonstration seems to me to be the recognition of the distinctions between a *hemisphere* and a *prothalamus*. The former is a *lateral* mass containing a ventricle. The latter is, strictly speaking, a *median* mass inclosing the anterior portion of the third ventricle, which opens laterally into the hemisphere ventricles through the foramina of Monro. Its anterior boundary is the lamina terminalis. In sharks and skates the prothalamus persists as the hinder part of the nearly solid mass in front of the optic lobes. The true hemispheres project forward to a greater or less extent, as shown in a previous paper (27). This median mass also persists in *Ceratodus*, although Prof. Huxley calls it *lobus communis* (16, 30). With *Chimæra* the lamnia terminalis is reduced to a slight commissure, and the outer walls of the prothalamus, almost disconnected, become lateral solid masses, the *hemiprothalami*. The true hemispheres persist, with their lateral ventricles. But with Ganoids and Teleosts the hemispheres seem to be rudimentary, and their name has been usually applied to the hemiprothalami. The mesothalami may be more or less elongated in various genera.

With the air-breathing vertebrates the hemispheres are prominent, and the prothalamus correspondingly reduced. But I think its ventricle can be recognized in all, especially embryos, as the space bounded in front by the lamina terminalis, and opening laterally through the foramen of Monro. A more extended consideration of this matter must be reserved for a separate paper.

Taxonomic Considerations.—The views of Müller, Valentin, and Mayer respecting the affinities of the Holocephala are given in the historical sketch. Gegenbaur (14, 408) makes the group of equal value with Teleosts, Ganoids, and Selachians [Plagiostomes].

Huxley, in speaking (16, 41) of Müller's separation of the Holocephala, expresses himself as follows :—

"It appears to me that he might have been justified in going still further; for, considering, in addition to the cranial characters, the structure of the vertebral column, and of the branchiæ, the presence of an opercular covering to the gills, the peculiar dentition, the almost undeveloped gastric division of the alimentary canal, the opening of the rectum quite separately from and in front of the uro-genital apertures, the relatively small and simple heart, the Chimæroids are far more definitely marked off from the Plagiostomes than the Teleostei are from the Ganoids."

I have only to add, upon the present occasion, that the conclusion which Prof. Huxley bases upon the consideration of other parts of the organization, seems to me fully confirmed by the structure of the brain of *Chimæra*, as described in the foregoing pages; the Holocephala seem to differ from the Plagiostomes more than the Ganoids differ from the Teleosts, and should form a primary subdivision of the fish-like vertebrates, like the Amphibia, Dipnoi, Ganoidei, Teleostei, Plagiostomes, and Myzontes or Marsipobranchs. (See, also, pages 227 and 228.)

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Explanation of Figures.[1]

Figures 1, 2, 4, and 15 are natural size. The remainder are enlarged two diameters.

Fig. 1. Brain of *Chimæra monstrosa*, ♂, from the left side.

Fig. 2. The brain is cut vertically and longitudinally on the median line so as to show the mesial surface of the right half.

Fig. 3. View of the hinder region, from above.

Fig. 4. The same region from below.

Fig. 5. The same region from above and in front, so as to show the optic lobes and the parts in front of them. The cerebellum is foreshortened.

Fig. 6. The optic lobes from above.

Fig. 7. The anterior portion of the medulla, showing parts which are naturally covered by the crebellum.

Fig. 8. Horizontal section of the optic lobes, the peduncles of the cerebellum, and the anterior portion of the medulla.

Fig. 9. Transverse section of the optic lobes in the direction of a line drawn from the anterior extremity of the cerebellum to the posterior margin of the hypoaria.

Fig. 10. Vertical transverse section of the cerebellum between the anterior and posterior laminæ. The corresponding portion of the medulla is not shown.

Fig. 11. Horizontal section of the cerebellum, showing the interior from above.

Fig. 12. Outer surface of the left anterior region, olfactory lobe (separated), hemisphere, prothalamus, and part of the mesothalamus.

Fig. 13. The same (exclusive of the olf. lobe) from above.

Fig. 14. The same from below.

Fig. 15. The same in horizontal section.

Fig. 16. Left olf. lobe, showing the surface by which it was attached to the hemisphere, and the slight depression which constitutes the olf. ventricle.

Fig. 17. The same, showing the anterior surface.

[1] The figures were drawn from nature, and on stone, by Miss G. D. Clements, a student in the Natural History course at Cornell University.

Fig. 18. The anterior surface of the hemisphere corresponding to the surface shown in fig. 16.

Fig. 19. The medulla after removal of the dorsal and lateral lobes so as to show the roots of the vagus.

Fig. 20. Transverse section of the medulla near the hinder end of the lobes.

Fig. 22. The same in front of the nerve roots.

Fig. 23. Transverse section of the spinal cord. (These three figures are mainly diagrammatic, proper microscopic sections not being available.)

Explanation of Signs.

The names of the principal divisions are indicated by capitals, as follows:—

S C, spinal cord.
M, medulla oblongata.
C, cerebellum.
O, optic lobes.
T, thalamencephalon.
H, hemispheres.
O l, olfactory lobes.

The following are designations of the subdivisions arranged under their respective divisions. The numbers indicate the figures in which the parts are shown.

S C, spinal cord.

- *v*, (4, 20, 21, 22) ventral (anterior) median fissure.
- *d*, (3, 22) dorsal (posterior) median fissures.
- *v c*, (4, 22) ventral columns.
- *d c*, (1, 3, 22) dorsal column.
- *v l*, (4, 22) ventral lateral line.
- *d l*, (1, 3, 22) dorsal lateral line indicated by a series of nerve roots.
- *l c*, (1, 22) lateral columns.

M, medulla oblongata.

- IV, (2, 3, 20, 21) fourth ventricle.
- *l*, (2, 3) ligula.
- *n o*, (1) origins of nerves.
- *r*, (1) restiform bodies, continuations of the posterior columns.
- *m t*, (19, 20) median tracts seen in the fourth ventricle.

i t, (19, 20) intermediate tracts.
n t, (19, 20) nodular tracts.
v r, (19, 20) roots of vagus nerve.
d m, (1, 2, 3, 20, 21) dorsal lobes of medulla.
d m′, (1, 3, 5, 7) anterior convoluted portion of the same.
l l, (1, 20, 21) lateral lobes of medulla.
l l′, (1, 3, 4, 5, 7, 8) anterior convoluted portion of the same.

C, cerebellum.
c, (1) crus or peduncle of the cerebellum.
d f, (3, 5, 10) dorsal furrow..
c a, (2, 8, 11) anterior lamina.
c p, (2, 8, 11) posterior lamina.
i f, (11) furrow on anterior surface of posterior lamina.
c′, (2, 8) posterior cerebellum.
c v, (2, 8, 10, 11) ventricle of the cerebellum.
i, (2) communication between the fourth ventricle and the cerebellar ventricle.

O, optic lobes.
c c, (1, 2, 9) crura cerebri supporting optic lobes.
t, (1, 5, 9) protuberance upon the crus cerebri.
o v, (2, 8, 9) optic ventricle, median and larger portion.
o v′, (9) median ventral portion.
o v′′, (9) lateral dorsal portions.
o v l, (2, 9) lobes of the optic ventricle.
o v p, (2) constricted communication of the optic with the cerebellar ventricle.
o v a, (2) constricted communication with the third ventricle.

T, thalamencephalon.
b t, (1, 2) basithalamus.
h, (1, 2, 4, 5) hypoaria, or lobi inferiores.
h v, (2) ventricle of the hypoaria.
h f, (4) fissure of the hypoaria.
t c, (2) canal continuing forward from the optic ventricle; really part of the third ventricle.
t f, (5) foramen of the thalamus.
t l, (1, 2, 5) double cover over the foramen.
o c, (2, 4) optic chiasma.
o n, (1, 2, 4) optic nerves.

c t, (1, 2, 3, 4, 5, 12, 13, 14) mesothalamus.

p t, (1, 2, 12) prothalamus.

H, hemisphere.

f m, (2, 13, 15) foramen of Monro.

l v, (14, 15, 18) lateral ventricles.

x, (2, 13, 15) rounded thickening of outer wall of ventricles.

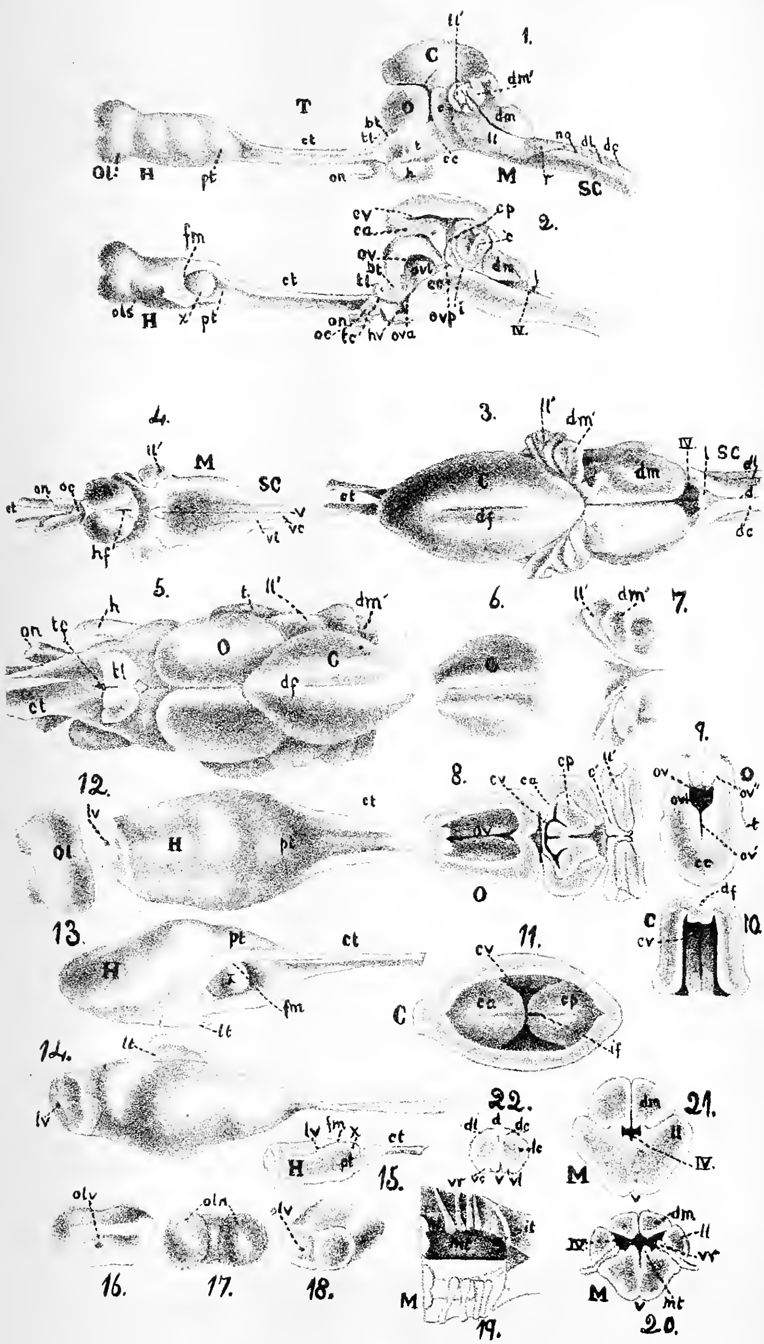
l t, commissure of the hemisphere (lamina terminalis).

O l, (1, 2, 12, 16, 17) olfactory lobes.

o l s, (2) suture between hemispheres and olfactory lobes.

o l v, (16) rudimentary olf. ventricle.

o l n, (17) two groups of olf. nerves.



Wilder on Brain of Chimæra.